Progress on Bialkali Photocathode Production at Argonne

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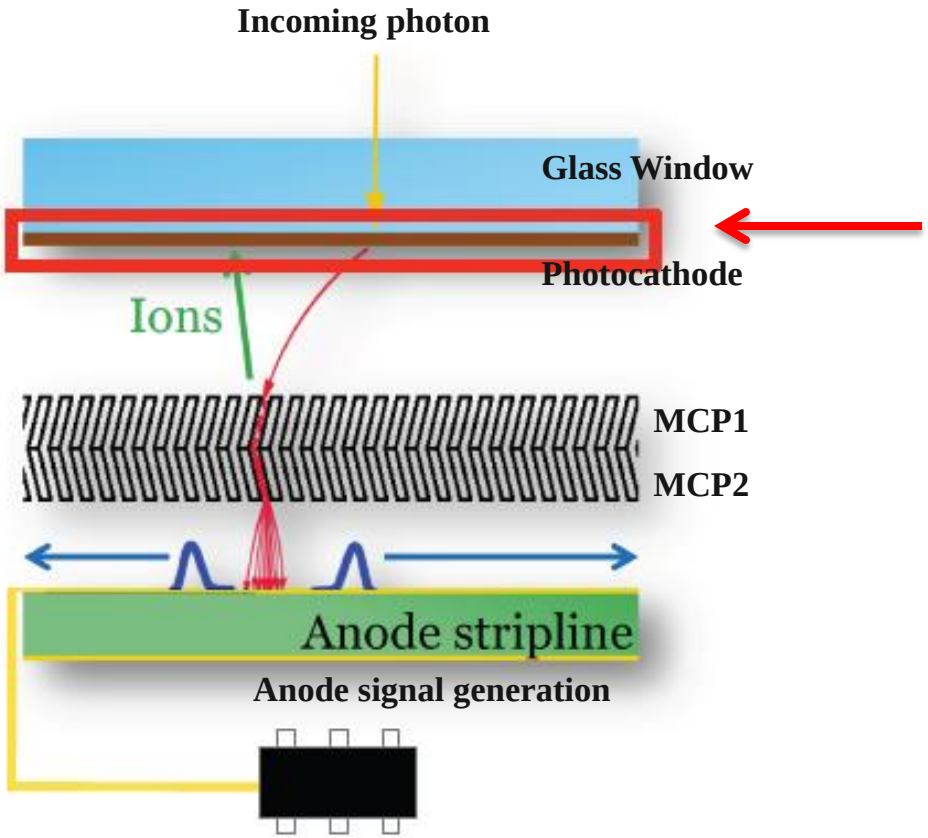
Tuesday, July 10th, 2012

Outline

- Motivation
- Small PMT Photocathode Growth and Characterization
- Large Area Photocathode Growth and Characterization
- Summary
- Future Work

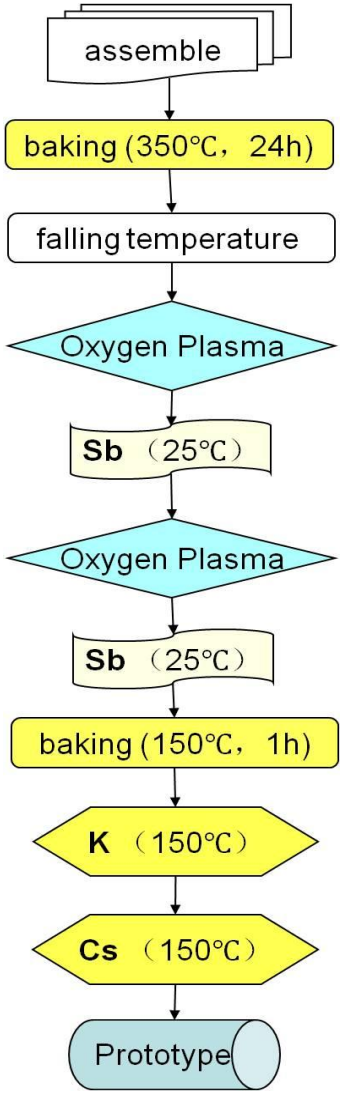
Motivation: Photocathode



Photocathode:
Conversion of photons to electrons

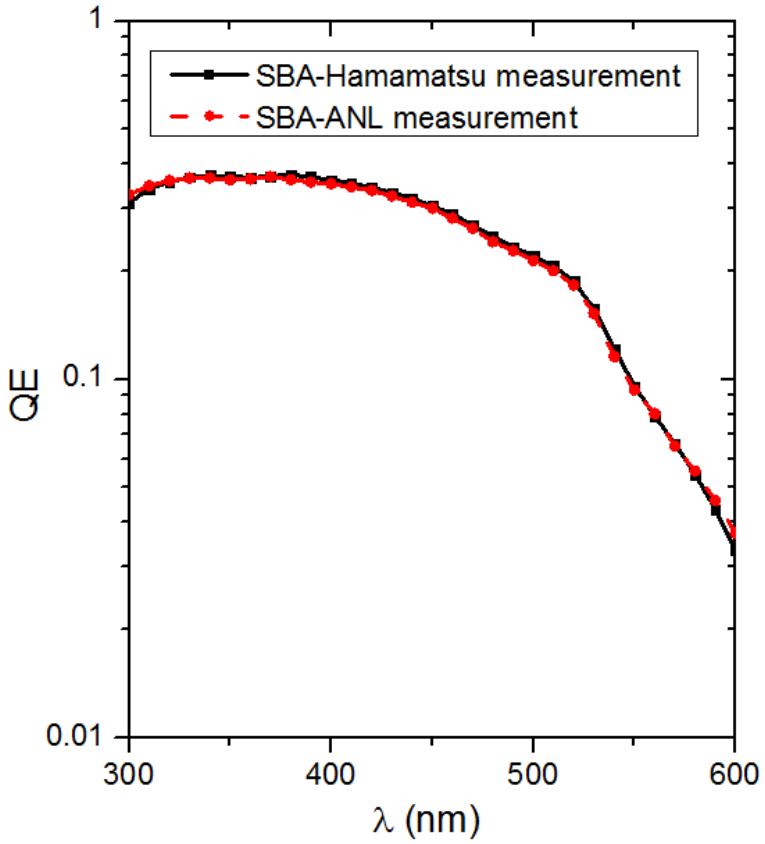
Many fundamental detector properties such as dark current, quantum efficiency, response time, and lifetime are determined by the properties of the photocathode.

Bi-Alkali Photocathode Deposition Process



Learn how to deposit photocathode and apply these to the fabrication of large area photocathode.

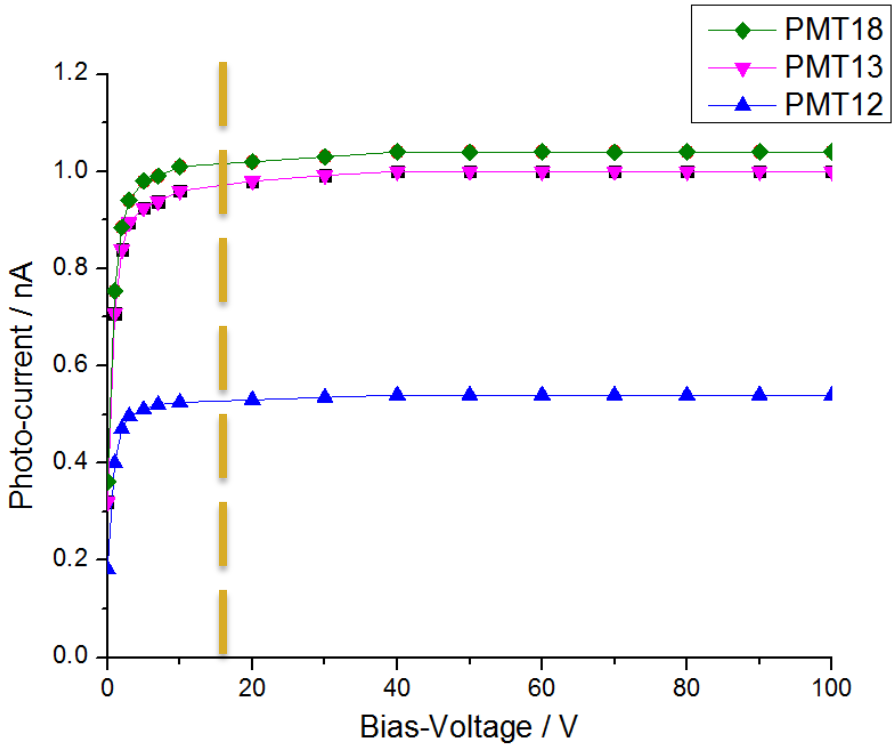
Commissioning of Optical Station



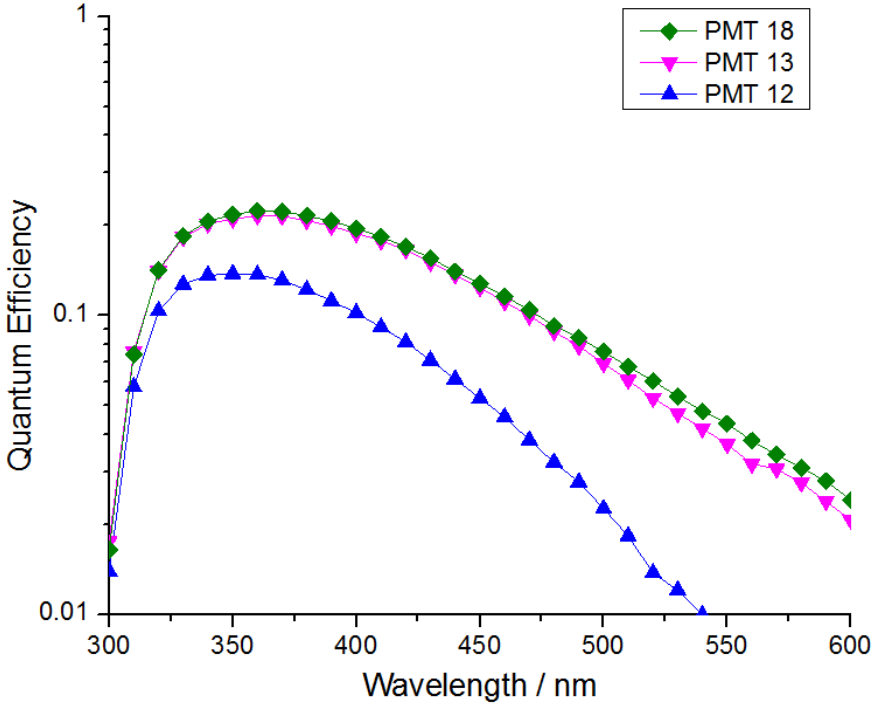
- Movable optical station can be shared with different growth facilities in the lab.
- QE measurement by Hamamatsu and ANL optical station agree well with each other indicating the home-built optical station is accurate.

Small PMT Photocathode Characterization

I-V Characteristic

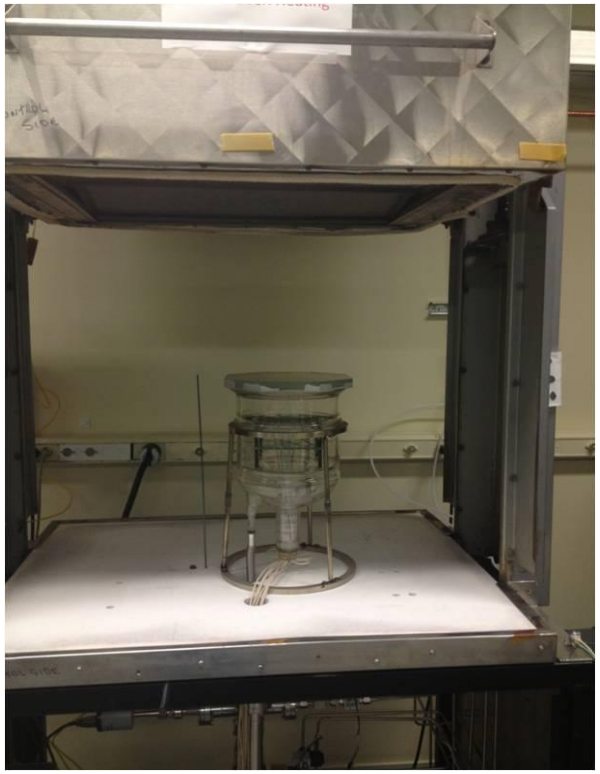


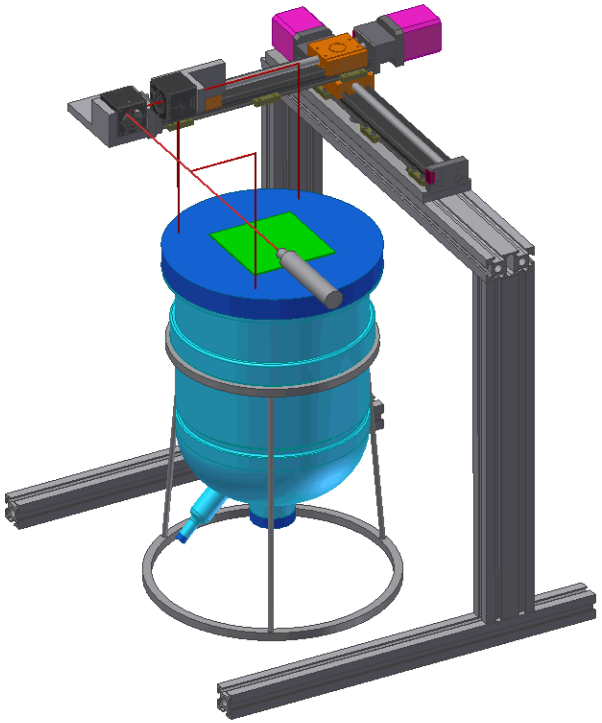
QE Measurement



- Cathodes exhibit characteristic I-V behavior, with QE as high as 24% at 370 nm.
- The quick drop at short wavelength is due to glass absorption.

The Chalice Design



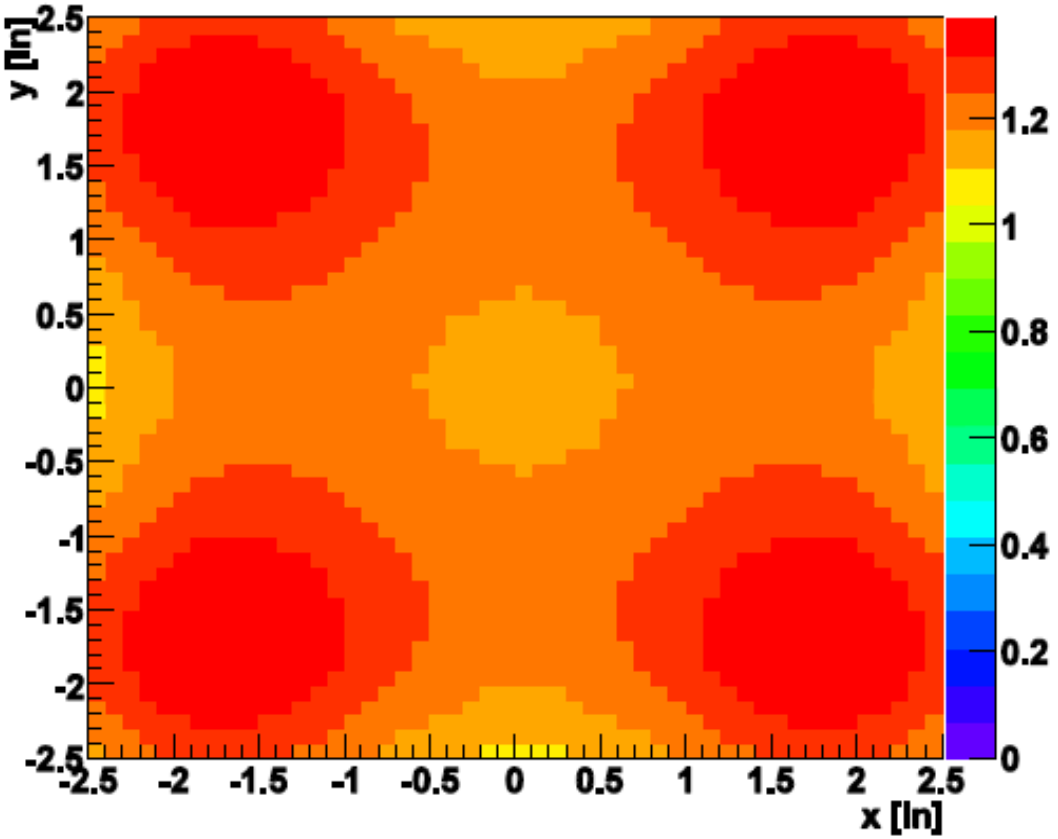


- Design is based on the small PMT tube, the chalice can be seen as a LARGE PMT tube.
- Top glass plate is replaceable for reuse.
- Chalice structure is supported by external legs.
- An X-Y scanner was designed and built for QE scan.

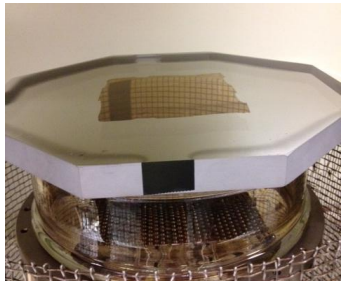
Sb Beads Arrangements for the Chalice (4’’X4’’)

- Numerical simulation of Sb thickness as a function of Sb beads arrangements and distance from window;
- 4 Sb beads arrangement
- 2.5” distance from the window;
- This arrangement produces sufficient uniformity on a 4”x4” window as our starting point;
- This assumes all the beads perform identically.

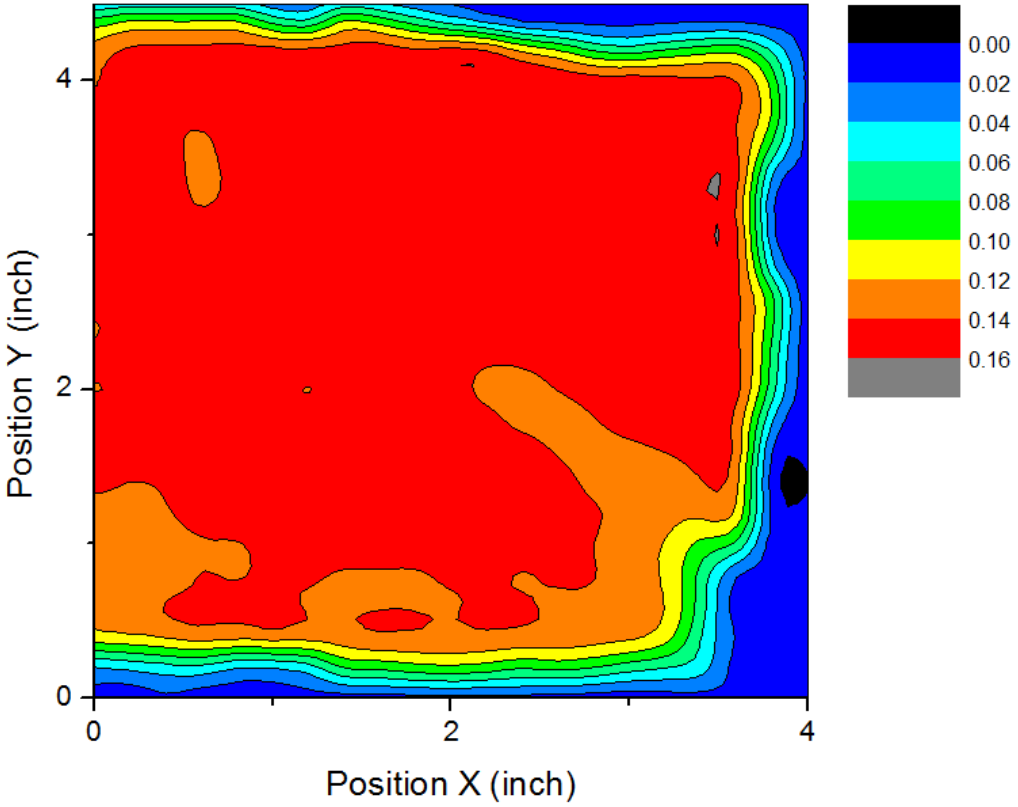
Simulation of relative Sb thickness

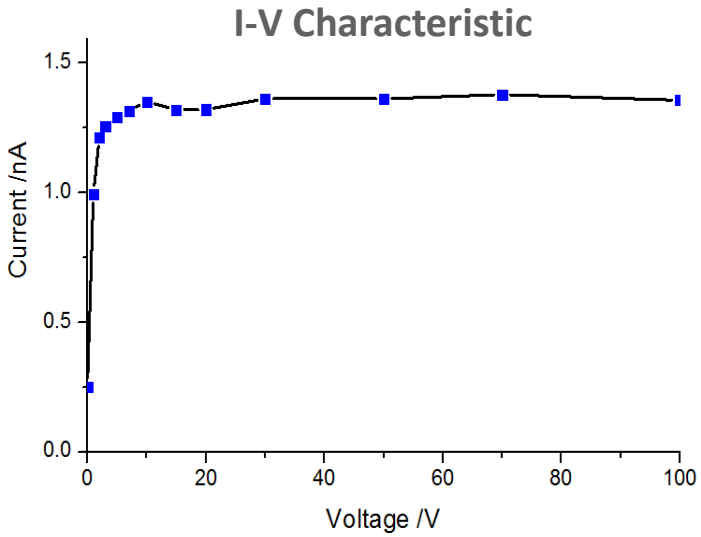


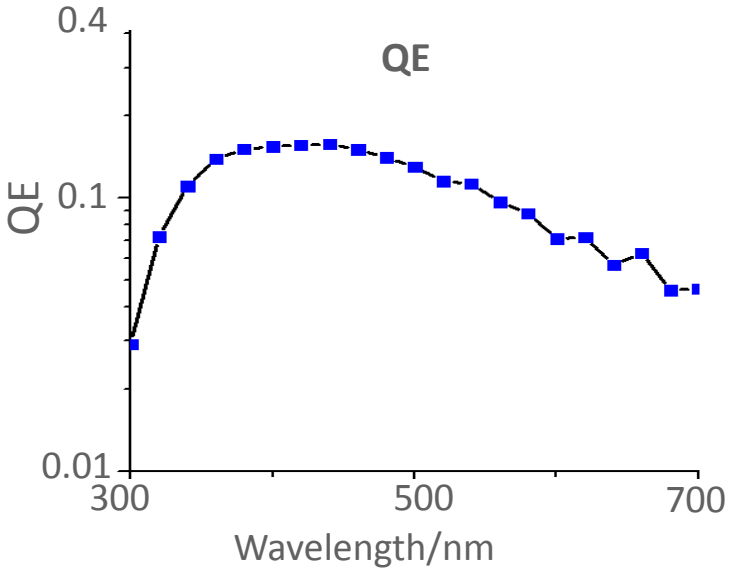
Chalice Photocathode Characterization (4’’X4’’)



4’’ X4’’ QE Map at 370 nm





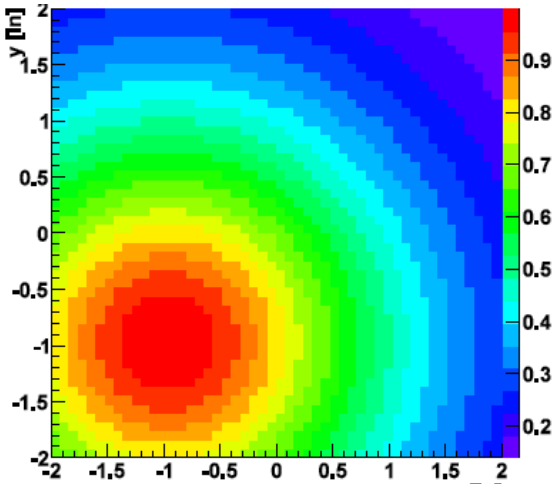


- QE at 370 nm is uniform (15%) at a large area.
- Plasma was not performed properly, due to low plasma power supply, impedance mismatch.

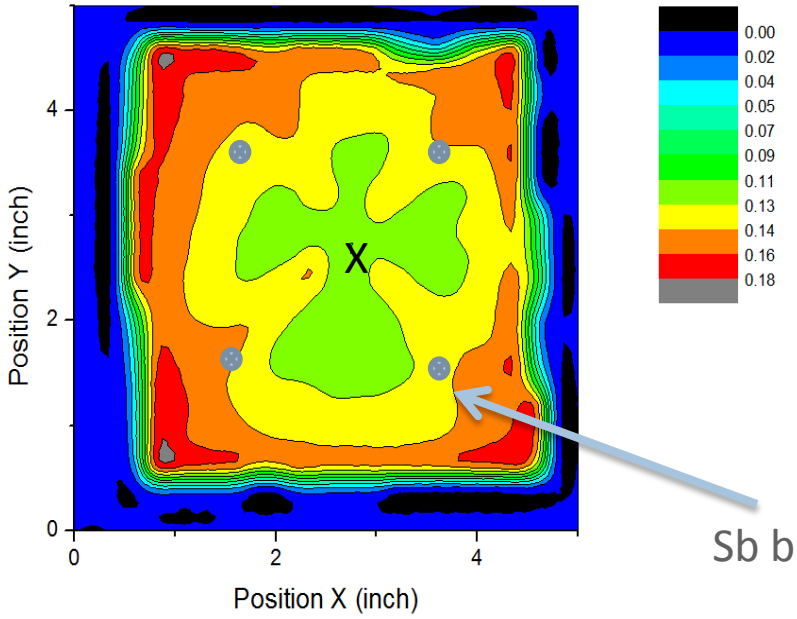
Comparison of QE Map and Sb Transmission Map

Center nail (“lightning rod”) for plasma generation

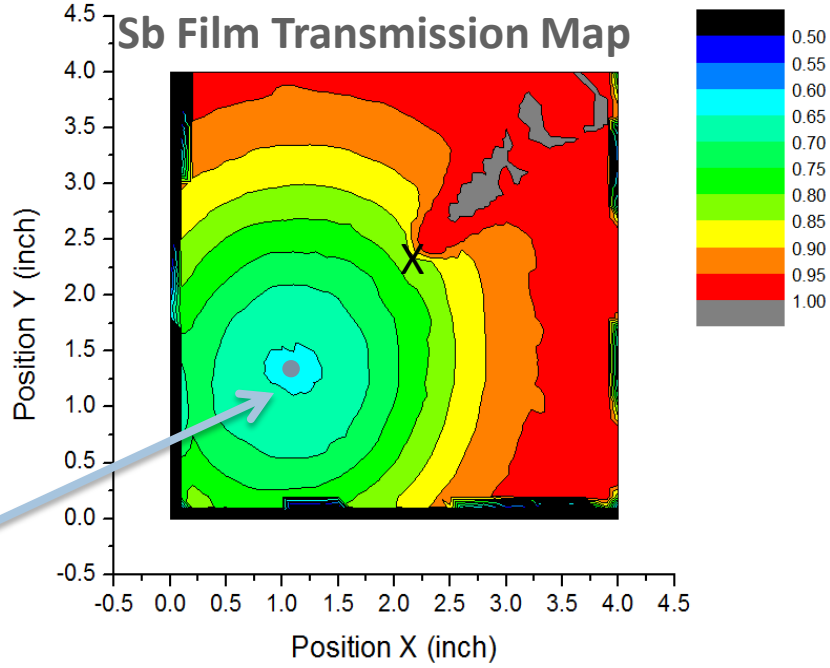
Simulation of relative Sb thickness



4”X4” QE Map at 370 nm



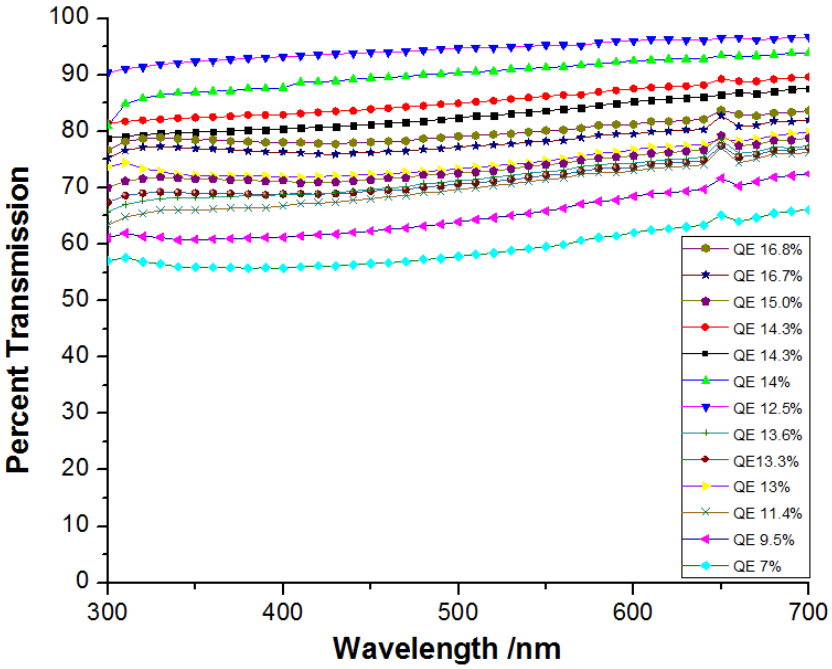
Sb Film Transmission Map

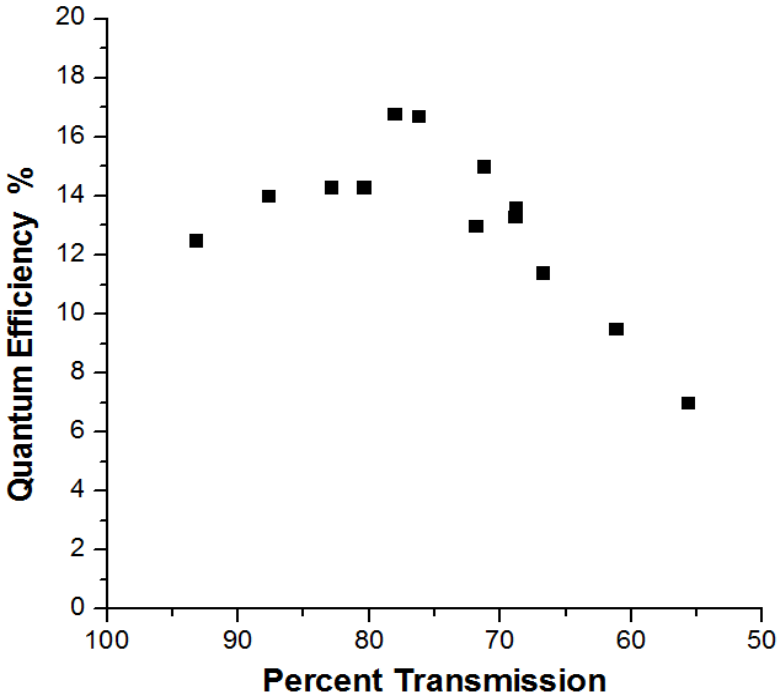


Sb bead

Center X: Lightning rod, which affect the Sb film deposition

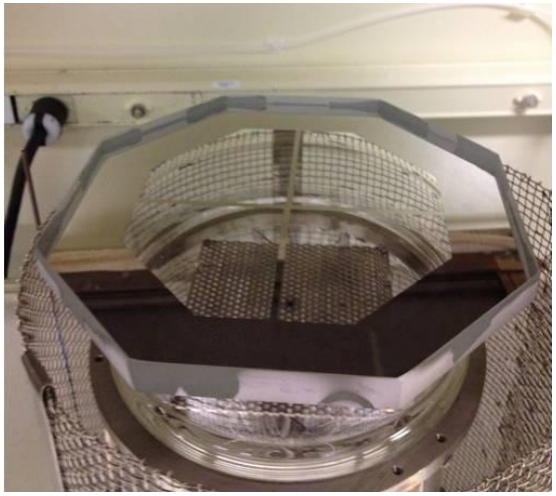
Sb Film Transmission Curve with Different Photocathode QE

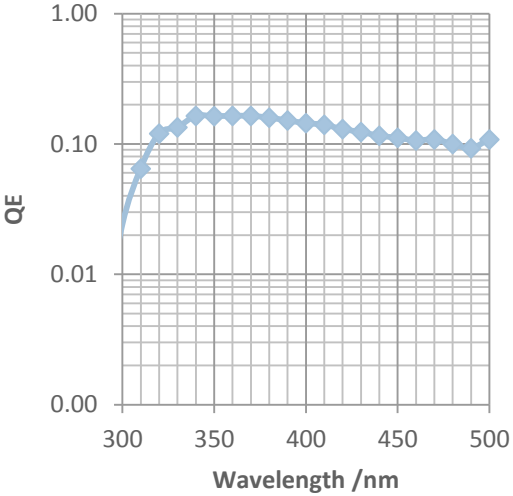




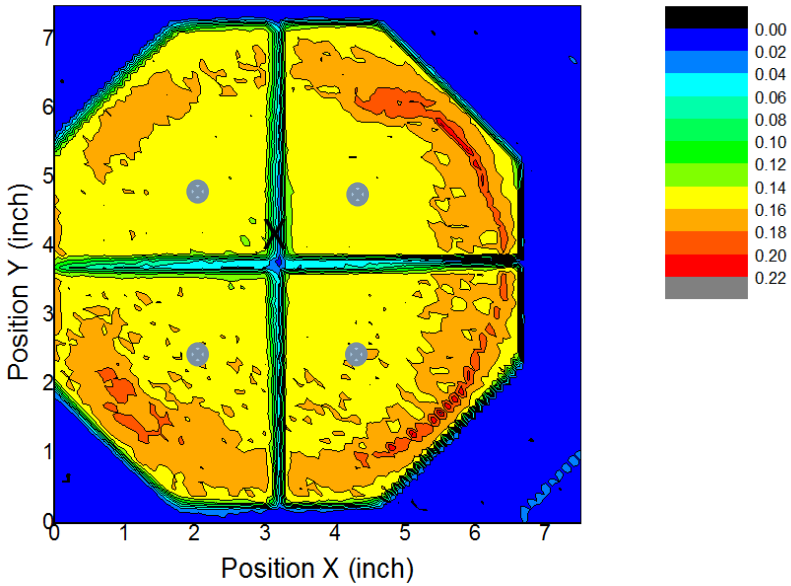
- Film transmission with known QE were measured and plotted.
- Film transmission increases as wavelength increases without regarding the QE value
- The film transmission values at 400 nm were chosen to plot the relation between KCs-Sb cathode QE and film transmission.
- The highest QE is around 78% Sb transmission (400nm beam).

Chalice Photocathode Characterization (7’’)

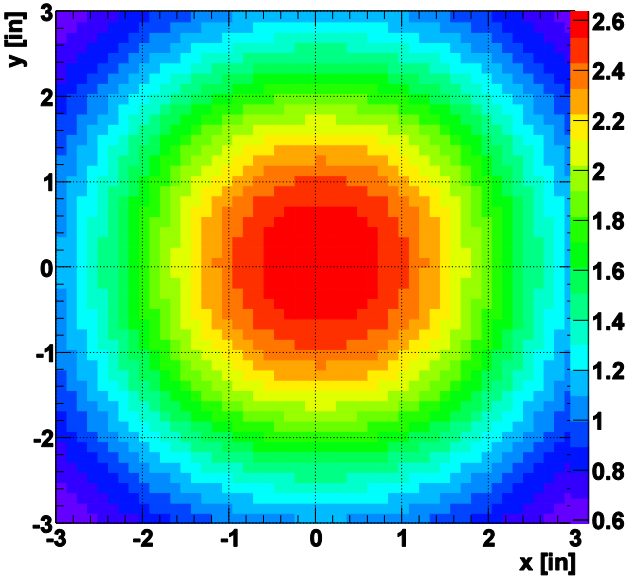




QE Map



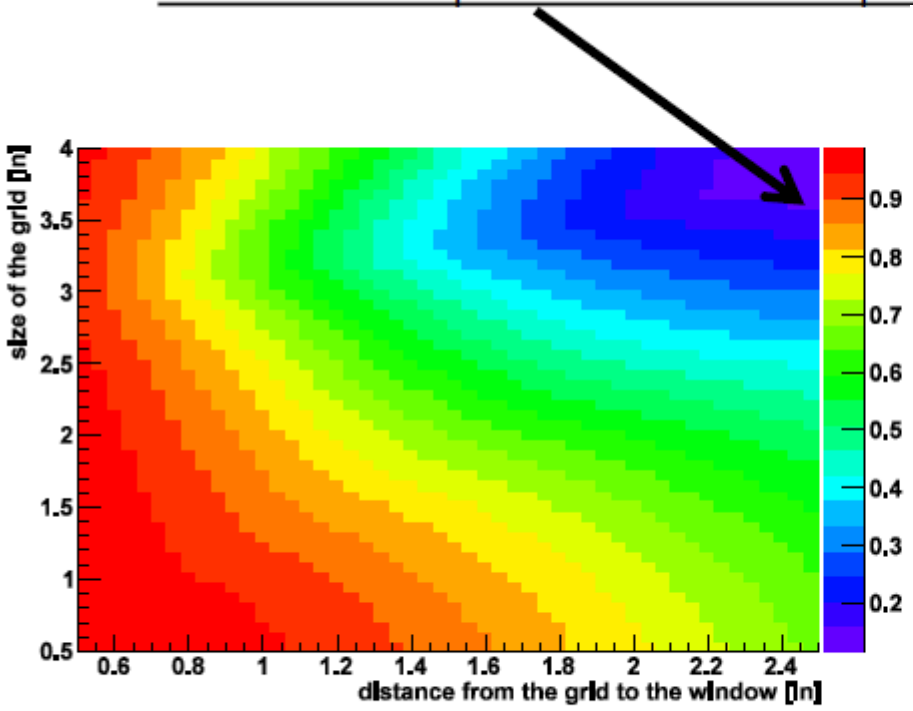
Simulation of Sb layer thickness



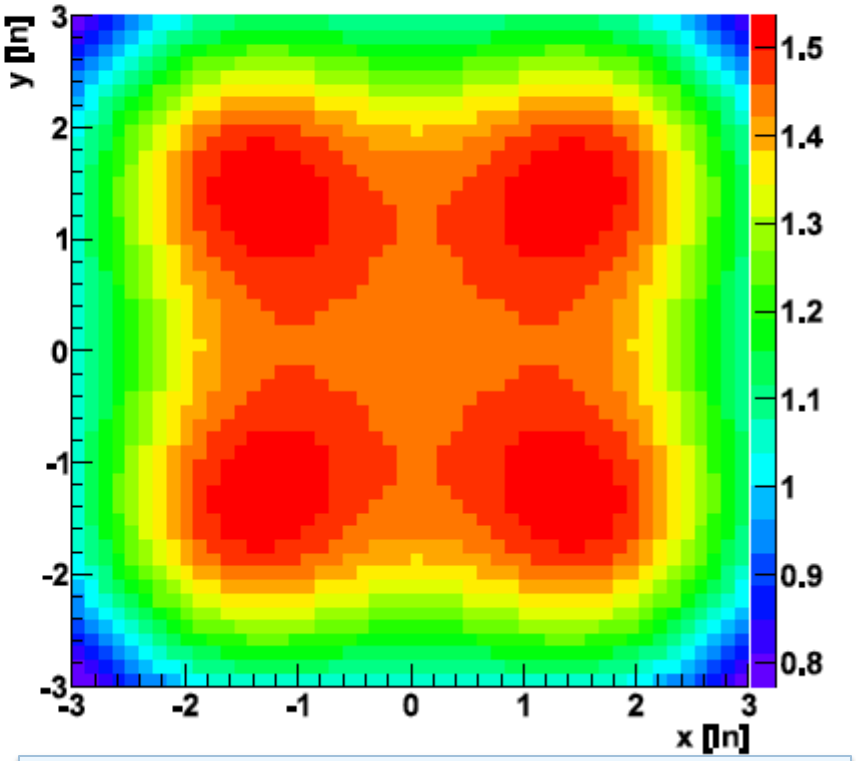
Flat cathode with average QE (~16%), the highest QE spot reaches over 22%, and the higher QE is at the corner area, which is the thinner Sb area.

Optimization for the 7’’ cathode

- Place the evaporators 3.5-4 in apart.



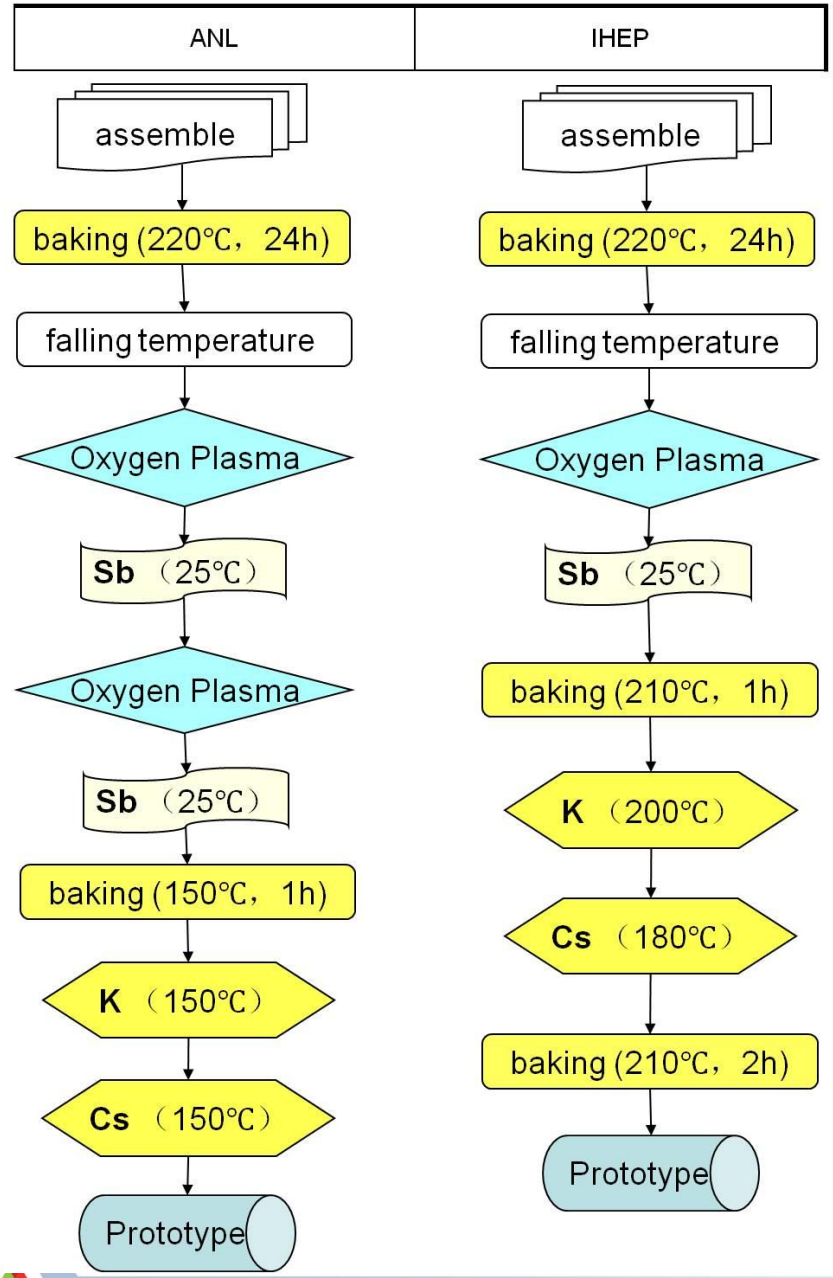
Sb uniformity distribution



Simulation of relative Sb layer thickness with evaporators 3.5 in apart

The Sb beads need to be placed further apart than the present place to obtain uniform Sb thickness.

Collaboration visit form IHEP (China)



steps	ANL	IHEP
Oxygen Plasma	✓Pressure of the oxygen: **0.3 torr** ✓The voltage to the glass:**20KV** ✓Shape of the electrode: **tip**	✓Pressure of the oxygen: **10^{-2} torr** ✓The voltage to the glass: **700V** ✓Shape of the electrode: **planar**
Sb	✓Silk material: **Pt-Mo** ✓Monitor the reflection light by the Photodiode	✓Silk material: **Ni** ✓Look at by eyes
K	✓Outgas with small current (2A) during the baking time; ✓Monitor the photo current, till the increasing trend stops ✓ Continue the evaporation until photo current drops to 80% of the Max. value;	✓Outgas with the high frequency gun before baking; ✓Monitor the light current, till the increasing trend stops;
Cs	✓Outgas with small current (2A) during the baking time; ✓Monitor the photo response current, after the increasing trend stops, continue evaporation untill the current decreases to half of the peak current; ✓Stop baking the prototype	✓Outgas with the high frequency gun before baking; ✓Monitor the light current, till the increasing trend stops; ✓Continue baking the prototype at least 2 hours.

Summary

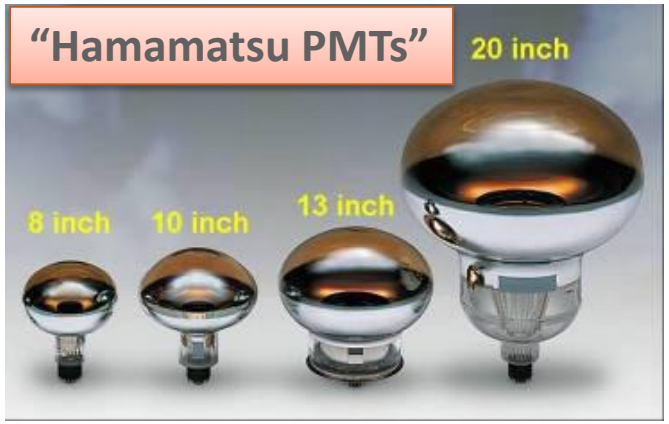
- Photocathode growth and characterization instruments were set up.
- PMT photocathodes with QE as high as 24% have been produced.
- Large area (4''X4'') photocathode with uniform QE (15%) were achieved even without oxygen plasma cleaning and oxidation.
- **Large area (7''X7'') flat** photocathode with average QE (~16%) was produced, the highest **QE value was 22%. → Currently we are optimizing thickness of Sb layer.**
- All photocathodes show typical I-V characteristics.
- QE of the photocathode is related to base Sb layer thickness.
- The optimized Sb thickness for KCs-Sb photocathode is around 78% transmission (400nm beam).

Next Steps

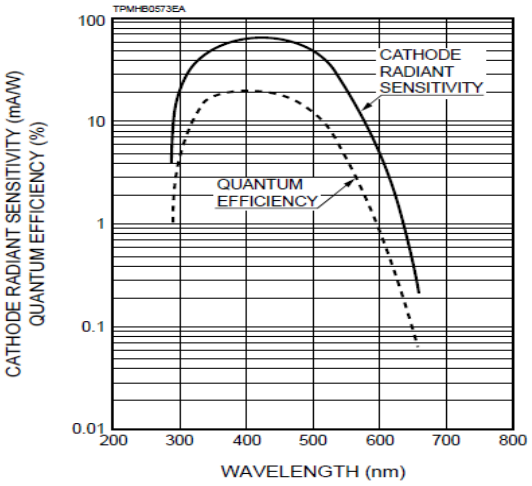
- Work out the plasma configuration to obtain uniform high-QE photocathodes.
- Complete absolute reflection measurement of Sb films and relate to the film transmission data (calibration).
- Study the effect of plasma cleaning and oxidation to the photocathode QE.
- Optimize the process for higher QE cathode based on the micro and macro studies.

Back Up

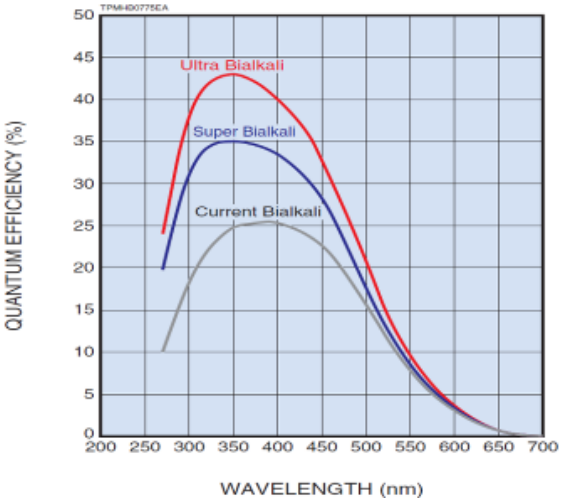
Motivation: Large Format PMTs



The QE of 20“ PMT-R3600



The QE of SBA/UBA

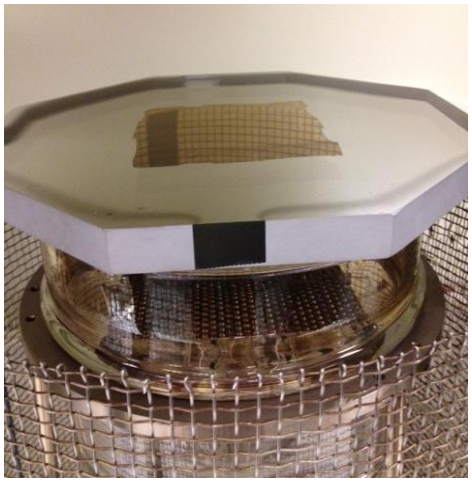


High QE PMTs: Super Bi-Alkali: SBA (35%) and Ultra Bi-Alkali: UBA (43%) are only available in small format (< 4" diameter ?)

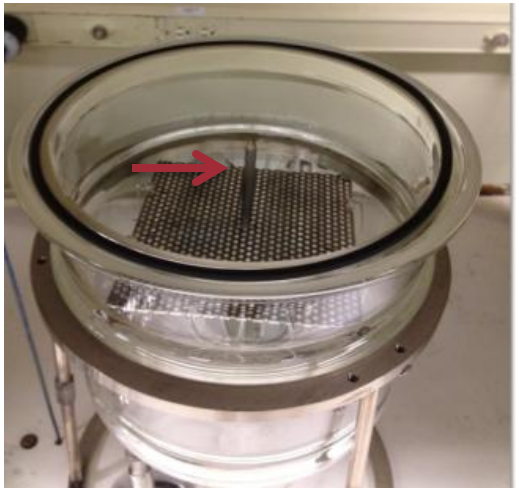
Can we reduce the volume of the large area PMTs and improve the Quantum Efficiency of Photocathode or Photon Detection Efficiency for the large area PMTs ?

The Affection of Center “nail” to QE uniformity

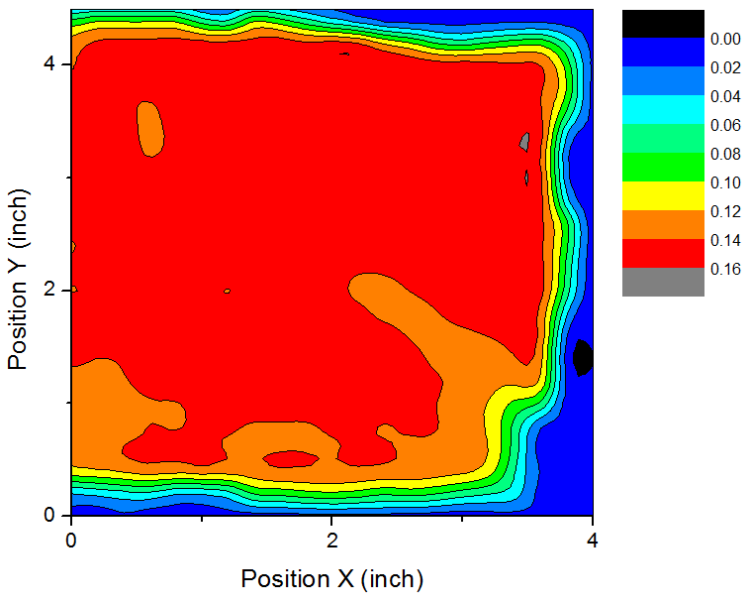
Chalice without center nail



Chalice with center nail



QE Map at 370 nm



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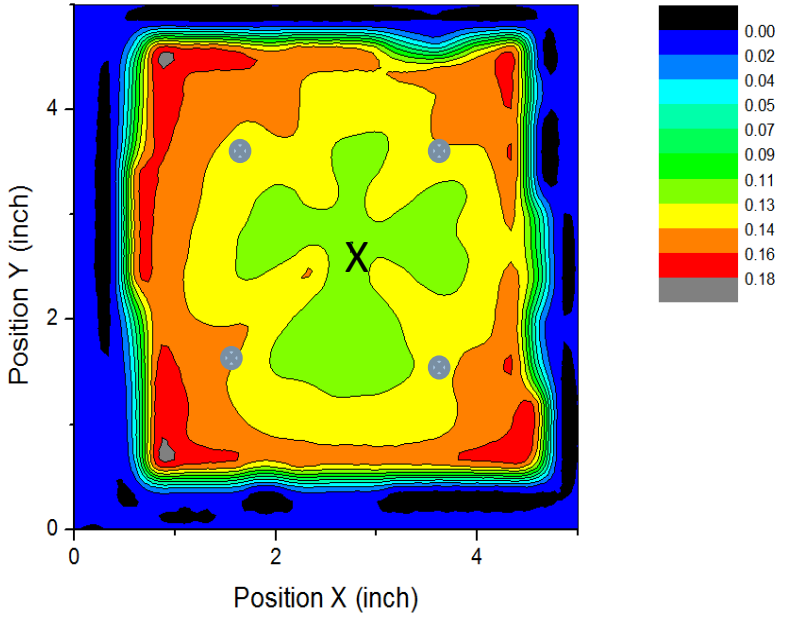
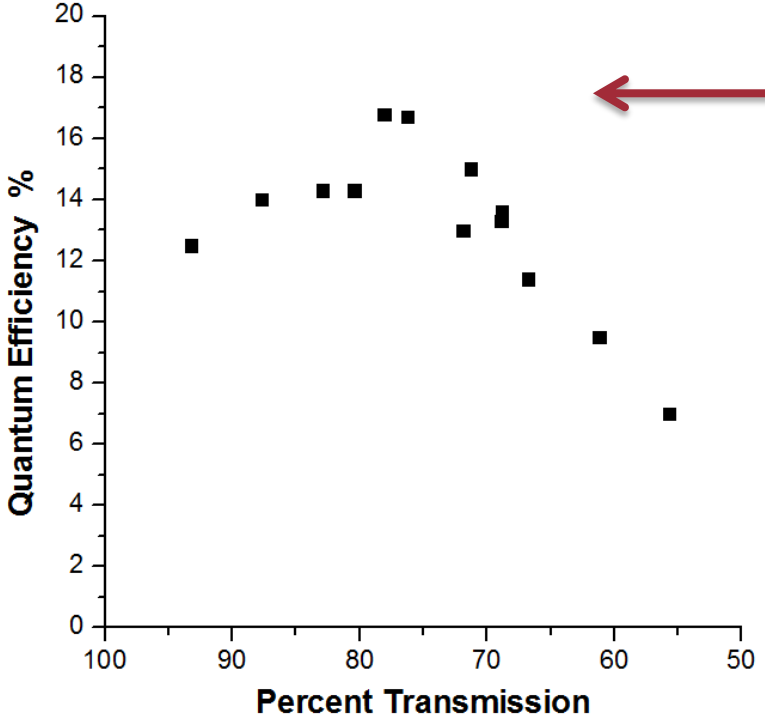


Relation between Cathode QE and Sb Film Transmission

KCs-Sb Photocathode



Relate the QE of the KCs-Sb cathodes with the Sb film transmission at 400 nm.

Cs-Sb Photocathode

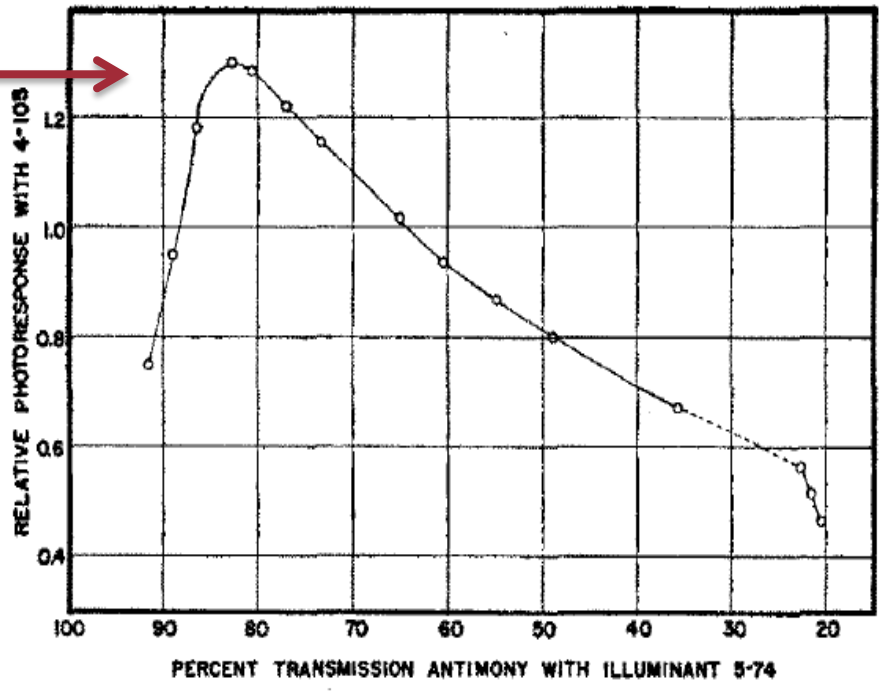


FIG. 5. Photoresponse in arbitrary units of Cs—Sb under reverse illumination *vs* transmission in percent of the original antimony

MARTIN ROME, *J. Appl. Phys*, **26**, 166, 1955

➢Note that the highest QE is around 78% Sb transmission (400nm beam), similar to that of Cs-Sb cathode at around 82% Sb transmission (blue light) as reported.